J. Cotton Res. Dev. **36**(2), 129-135 (July, 2022) **ISSN No. 0972-8619**

Studies on economic heterosis for yield and morphological traits in American cotton (*Gossypium hirsutum* L.)

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Abstract : The objective of this study was to determine economic heterosis of hybrids, with respect to seed cotton yield and its contributing traits. Forty four F_1 hybrids generated by crossing 4 lines with 11 testers in Line x tester design in the year 2015 along with check hybrid HHH 223 were grown in randomized complete block design with 3 replications in *Kharif 2016* for their evaluation. Among forty four crosses, thirty F_1 hybrids exhibited significant positive heterosis for seed cotton yield. Maximum heterosis for yield of seed cotton per plant was registered by the cross H 1353 x H1499 (119.28%) succeeded by H1353 x H1480 (112.67%), H1353 x H1491 (105.23%), H 1098i x H 1481 (93.86%), H 1353 x H 1501 (87.54%) and H 1316 x H1491 (82.57%). Crosses exhibiting high heterosis for seed cotton yield/plant also reported high heterosis for bolls/plant and boll weight. The test hybrids showed heterosis of more than 80 per cent and hence permit their further testing over several locations for commercial utilization.

Key words: American cotton, economic heterosis, line x tester, seed cotton yield

Cotton is the "King of Fibers" and plays a major on economics and social affairs of the world. It is a commercial crop grown in about 111 countries of the world. India is the leading country in terms of area under cotton cultivation and raw cotton production in the world. Per hectare productivity in India still much lower compared to many leading cotton growing countries. Development of new variety with high yield and fibre quality is the primary objective of all cotton breeders. Heterosis breeding is an important genetic tool to facilitate yield enhancement and help to enrich many other desirable quantitative and qualitative traits in crops. Economic heterosis or hybrid vigour is the increment in performance of a hybrid in relation to standard check and can assume positive or negative values. Cotton is an often cross pollinated crop and amenable for both heterosis breeding as well as hybridization followed by selection in subsequent generations. The phenomenon of heterosis has proven to be the most important genetic tool in boosting the yield of self as well as cross pollinated crops and is considered as the most important breakthrough in the field of crop improvement. The exploitation of hybrid vigour in cotton on commercial scale has become feasible and economical due to easy hand emasculation and pollination. Line × Tester analysis provides a systematic approach for the detection of appropriate parents and crosses in terms of investigated traits.

Heterosis breeding is useful to identify the cross combinations which are promising in conventional breeding programme. India is pioneer in commercialization of heterosis in cotton and noticeable heterosis is also reported in cotton by many workers in cotton (Dave, (2014), Tuteja, (2014), Lingaraja *et al.*, (2017a), Vekariya *et al.,* 2017, Chakholoma *et al.,* 2021). In the cotton crop, a plethora of studies has been conducted for the classification of genotypes on the basis of DUS traits (Sagar *et al.*, 2019, Kumar *et al.*, 2021). The yield contributing traits and fibre quality parameters are the important character in cotton improvement programme.

Heterosis breeding is an important breeding technique to facilitate yield enhancement and help to enrich many other desirable quantitative and qualitative traits in crops. Generally, the development of cotton hybrids/varieties for higher lint yield with desirable fibre quality parameters is the most important objective of the cotton improvement programs.

The magnitude of heterosis lay the foundation for the selection of desirable genotypes for developing superior F_1 hybrids, thus to exploit hybrid vigour or constructing the better gene pool after growing for successive ages. Heterosis studies are conducted to estimate extent of useful heterosis so as to substantiate the per se mean performance. Heterosis is significant to plant breeders in the sense that it is one of the techniques for increasing productivity of many crops.

MATERIALS AND METHODS

The present investigation was undertaken to study economic heterosis for yield and other traits in American cotton (*Gossypium hirsutum* L.). Forty four F_1 hybrids were derived by crossing four lines with eleven testers in line x tester mating design in the year 2015. The experimental materials consisted of 44 F_1 hybrids and one check hybrid HHH 223 were grown in Cotton research area, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during *kharif,* 2016. Each entry was sown in single row of 6.0 meter length adopting a spacing of 67.5 cm between rows and 60 cm between the plants in randomized block design with three replications. All the recommended packages of practices were followed from sowing to picking. Observations were recorded on randomly selected five competitive plants from each entry for days 1^{st} flowering, plant height (cm), monopods /plant, sympods /plant, bolls /plant, boll weight (g), seed cotton yield /plant (g) and the data on ginning outturn (%), seed index (g) and lint index (g) were taken in cotton field lab of Cotton Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University.

The analysis of variance was performed to test the significance of the differences among parents and F_1 hybrids/crosses for all characters. The analysis of variance was carried out as per the standard statistical method. The estimates of economic heterosis of F_1 hybrids over commercial check HHH 223 were calculated as given below:

$$\text{Over commercial check (CC) per cent heterosis in F1} = \frac{\overline{F_1} - \overline{CC}}{\overline{CC}} \times 100$$

Where,

CC = performance of commercial check

F_1 = Performance of across

RESULTS AND DISCUSSION

In most crops, high mean values for characters are desirable and cotton is not exceptional. However lower mean values for days to first flower and monopods/plant are desirable in cotton. The analysis of variance (Table 1) indicated significant variation among the genotypes for all the characters except days to 1^{st} flower were exhibiting the highly significant differences in analysis of variance. By this it was designated that the material selected for the current investigation was quite appropriate for further genetical analysis as remarkable amount of genetic variation showed by the experimental material under study.

Table 1 : Analysis of variance for different characters under study in upland cotton

Source of Variation	D.F	Days to 1st flower	Plant height (cm)	Monopods/ plant	Bolls/ plant	Boll weight (g)	Ginning outturn (%)	Seed index (g)	Lint index (g)	Seed cotton yield/plant (g)
Replication	2	319.54	277.34	0.22	139.29	1.97	8.49	0.02	0.18	17.57
Treatment	59	7.46	**366.60****	**0.56****	**59.49****	**0.27****	**29.86****	**0.61****	**0.72****	**1,013.71****
Error	118	18.77	181.75	0.12	10.60	0.09	11.06	0.13	0.13	118.26

*Significant at P=0.05, **Significant at P=0.01.

Heterosis for yield and its attributing traits:

The ultimate aim of cotton breeder is to develop new varieties/ hybrids with high seed cotton yield with good fibre quality. Heterosis breeding is an important genetic tool to facilitate yield enhancement and help to enrich many other desirable quantitative and qualitative traits in crops. Seed cotton yield in cotton is one of the most important economic characters and is the final product of the multiplicative interaction of contributing traits. In present study the magnitude of economic heterosis was observed for all the nine traits by comparing with the standard check HHH 223. The values of the economic heterosis for individual crosses recorded for all nine characters are given in Table 2. For yield, which is major aspect of breeding, 16 hybrids showed heterotic value of more than 60 per cent. Ten most promising hybrids for seed cotton yield have been listed in Table 3.

Earliness in flowering is desirable in cotton and hence the cross combinations having negative heterosis for days to first flower were desirable. The range of heterosis varied from -10.42 to 4.03 per cent for days to 1st flower and H 1465 x H 1464 (4.03%) was a single cross which exhibited significant positive heterotic effects, while ten hybrids showed significant negative heterotic effects. Economic heterosis for this character ranged from- 4.1 to 29.84 per cent and among all forty four crosses, the total number of crosses showed positive significant heterosis for plant height (tallness) was twelve. Foremost cross showing maximum (29.84%) heterosis were H 1465 x H 1500 accompanied by H 1353 x H 1500 (29.16%), H 1353 x H 1464 (26.65%) and H 1098i x H 1464 (20.96%). Plant height is a main morphological trait in cotton exhibited heterosis in both the directions and plant height plays a considerable role in deciding the morphological frame work relating to plant type, duration and productivity. In case of plant height, out of 44 intra *G. hirsutum* crosses, 12 crosses exhibited maximum positive significant heterosis for plant height (tallness). All findings were in line with the results recorded by Jaiwar *et al.,* (2012), Dave *et al.,* (2014), Pushpam *et al.*, (2015), Reddy *et al.,* (2016), Sivia *et al.,* (2017), Chakholama *et al.,* (2021).

Economic heterosis for monopods/plant over standard check was ranging from -28.08 per cent (H 1353 x H 1481) to 41.15 per cent (H 1465 x H 1490). Out of total forty four crosses, five crosses showed highly positive significant heterosis for monopods and three crosses showed negative heterosis. The crosses representing high significant positive heterosis for monopods were H 1465 x H 1481 (33.46%), H 1098i x H 1464 (33.46%) and H 1353 x H 1504 (28.08%). Heterosis for monopods was registered by the earlier workers Jaiwar *et al.,* (2012), Dave *et al.,* (2014) and Sawarkar *et al.,* (2015), Reddy *et al.,* (2016), Sivia *et al.,* (2017) and Bandhavi *et al.,* (2018). The range of heterosis shown by this trait was -18.17 to 69.25 per cent. Out of all forty four crosses only seventeen crosses were found to exhibit maximum significant positive heterotic values for this yield component, whereas not even a single hybrid showed significant negative heterotic effects. Highest heterosis value for number of bolls/plant was reported in hybrids H 1353 x H 1491 (69.25%), H 1353 x H 1499

Table 2 : Extent of heterosis for the crosses in different characters in upland cotton

Sr. No.	Hybrids	Days to 1st flower	Plant height (cm)	Monopods / plant	Bolls/ plant	Boll weight (g)	Ginning outturn (%)	Seed index (g)	Lint index (g)	Seed cotton yield / plant (g)
1	H1316 x H1464	**-10.42****	14.81	20.38	**25.25***	**17.67***	-5.83	10.34	-2.33	**62.71****
2	H1316 x H1470	-3.53	**20.73****	18.08	11.44	**16.33***	-3.27	6.90	1.63	**30.85***
3	H1316 x H1481	-3.70	8.20	20.38	**40.48****	13.67	**-17.44****	**27.59****	**-28.37****	**70.86****
4	H1316 x H1480	-1.18	7.29	**-25.77***	**33.44****	**17.00***	-7.57	**17.24****	-6.51	**71.83****
5	H1316 x H1490	-2.69	-4.10	-10.38	17.60	3.00	3.41	**17.24****	6.05	26.10
6	H1316 x H1491	-0.50	4.78	15.38	**36.69****	**20.33***	-4.57	8.62	-7.91	**82.57****
7	H1316 x H1499	-4.20	2.97	-18.08	13.20	7.67	-2.30	8.62	0.47	**31.20***
8	H1316 x H1501	2.02	13.44	-18.08	16.15	2.33	0.02	**18.97****	7.44	23.54
9	H1316 x H1500	-1.68	14.81	-10.38	20.55	13.00	3.87	**37.93****	**20.47****	**50.39****
10	H1316 x H1504	**-4.37***	14.58	-2.69	5.90	7.67	3.60	8.62	3.02	18.92
11	H1316 x H1505	**-7.06****	11.39	-7.69	0.88	1.67	**18.17****	0.00	**31.63****	10.97
12	H1353 x H1464	-1.01	**26.65****	-2.69	7.92	**18.00***	**24.36****	**18.97****	**-20.70****	**38.82***
13	H1353 x H1470	2.69	12.98	-12.69	-5.28	7.33	-2.27	**10.34***	0.93	2.65
14	H1353 x H1481	**-4.87***	-0.23	**-28.08***	18.21	15.00	-0.31	1.72	**-15.35***	**42.66****
15	H1353 x H1480	**-4.37***	10.93	5.00	**49.71****	**33.00****	3.94	**13.79***	-1.16	**112.67****
16	H1353 x H1490	**-4.37***	-1.13	-2.69	1.19	**16.33***	**-14.63***	**13.79***	**-45.58****	**31.19***
17	H1353 x H1491	-0.84	10.71	10.38	**69.25****	9.67	-10.38	8.62	-6.51	**105.23****
18	H1353 x H1499	**-4.03***	4.78	**-23.08***	**54.11****	**26.33****	1.81	8.62	-9.77	**119.28****
19	H1353 x H1501	2.69	12.76	20.38	**56.93****	8.00	-9.05	-6.90	-11.63	**87.54****
20	H1353 x H1500	-2.69	**29.16****	-5.00	**23.19***	14.67	-12.00	**17.24****	3.02	**56.90****
21	H1353 x H1504	**-4.20***	**15.95***	**28.08***	4.14	6.00	-4.64	-5.17	-12.56	21.69
22	H1353 x H1505	-1.68	3.87	2.69	**39.02****	11.00	-2.44	3.45	-2.79	**69.82****
23	H1098i x H1464	-1.85	**20.96****	**33.46****	-0.26	**32.33****	-3.14	**18.97****	**19.77****	**37.51***
24	H1098i x H1470	0.67	14.13	5.00	17.33	**28.00****	-6.70	3.45	-10.93	**63.68****
25	H1098i x H1481	2.69	**16.18***	**23.08***	**47.51****	19.00	-4.57	**13.79***	-7.21	**93.86****
26	H1098i x H1480	1.68	7.29	18.08	**25.25***	**21.00***	-8.73	8.62	-16.51	**61.62****
27	H1098i x H1490	-1.01	8.66	7.69	**28.77***	16.00	1.96	6.90	6.74	**61.62****
28	H1098i x H1491	-2.02	12.53	-5.00	10.87	**21.33***	-4.26	**22.41****	**-19.77****	**45.33****
29	H1098i x H1499	**-4.37***	6.38	0.00	-5.28	**20.67***	-8.68	**13.79***	**-15.81***	21.88
30	H1098i x H1501	-1.01	**16.40***	-10.38	1.76	7.00	9.87	5.17	**22.09****	14.78
31	H1098i x H1500	1.34	**18.68***	-12.69	0.62	7.33	-5.25	**13.79***	-2.09	18.76
32	H1098i x H1504	-0.67	14.35	-7.69	20.55	-5.67	0.19	6.90	-7.91	24.96
33	H1098i x H1505	-2.52	7.07	-5.00	-14.34	10.67	-7.69	**22.41****	-0.23	6.96
34	H1465 x H1464	**4.03***	**16.63***	5.00	-18.17	**35.00****	-7.69	**20.69****	-9.53	23.77
35	H1465 x H1470	-3.19	2.28	-2.69	17.60	3.33	-10.76	3.45	-11.63	**31.20***
36	H1465 x H1481	-1.01	**19.82****	**33.46***	12.32	15.00	**-16.18***	**22.41****	-13.02	**34.63***
37	H1465 x H1480	0.50	12.53	0.00	**28.46***	**22.33****	-6.94	**24.14****	6.74	**74.01****
38	H1465 x H1490	-3.36	3.65	**41.15****	**36.38****	**20.33***	**-27.94****	**25.86****	**-33.02****	**74.45****
39	H1465 x H1491	-0.34	9.57	-7.69	-16.98	6.00	**-29.73****	1.72	**-65.58****	-20.65
40	H1465 x H1499	-0.84	4.56	2.69	**24.37***	**17.67***	10.62	0.00	**27.67****	**56.05****
41	H1465 x H1501	-2.35	**19.37***	-20.38	-2.64	4.33	-3.51	**25.86****	4.65	7.90
42	H1465 x H1500	-2.69	**29.84****	-10.38	19.36	**25.33****	-1.72	5.17	3.95	**60.59****
43	H1465 x H1504	**-5.21***	12.98	-7.69	11.44	14.67	0.51	3.45	-0.93	**39.76****
44	H1465 x H1505	-3.87	9.34	-5.00	**31.98****	2.67	-0.68	**24.14****	11.86	**42.21****
45	HHH223	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*SignificantatP=0.05,**SignificantatP=0.01.

Table 3 : Best crosses on the basis of heterosis for seed cotton yield and related characters.

Sr. No.	Hybrids	Days to 1st flower	Plant height (cm)	Monopods /plant	Bolls / plant	Boll weight (g)	Ginning outturn (%)	Seed index (g)	Lint index (g)	Seed cotton yield / plant (g)
1	H1353 x H1499	**-4.03***	4.78	**-23.08***	**54.11****	**26.33****	1.81	8.62	-9.77	**119.28****
2	H1353 x H1480	-4.37*	10.93	5.00	**49.71****	**33.00****	3.94	**13.79***	-1.16	**112.67****
3	H1353 x H1491	-0.84	10.71	10.38	**69.25****	9.67	-10.38	8.62	-6.51	**105.23****
4	H1098i x H 1481	2.69	**16.18***	**23.08***	**47.51****	19.00	-4.57	**13.79***	-7.21	**93.86****
5	H1353 x H1501	2.69	12.76	20.38	**56.93****	8.00	-9.05	-6.90	-11.63	**87.54****
6	H1316 x H1491	-0.50	4.78	15.38	**36.69****	**20.33***	-4.57	8.62	-7.91	**82.57****
7	H1465 x H1490	-3.36	3.65	**41.15****	**36.38****	**20.33***	**-27.94****	**25.86****	**-33.02****	**74.45****
8	H1465 x H1480	0.50	12.53	0.00	**28.46***	**22.33****	-6.94	**24.14****	6.74	**74.01****
9	H1316 x H1480	-1.18	7.29	**-25.77***	**33.44****	**17.00***	-7.57	**17.24****	-6.51	**71.83****
10	H1316 x H1481	-3.70	8.20	20.38	**40.48****	13.67	**-17.44****	**27.59****	**-28.37****	**70.86****

*Significantat P=0.05, **Significantat P=0.01.

(54.11%), H 1353 x H 1480 (49.71%) and H 1353 x H1501 (56.93%). All these crosses were responsible for high heterotic value for seed cotton yield in these hybrids upto the range of 105.23, 119.28, 112.67 and 87.54 per cent respectively. Therefore the number of bolls was mainly responsible for increase in seed cotton yield. These findings are in conformity with the reports by Jaiwar *et al.*, (2012), Tuteja *et al.,* (2014), Sawarkar *et al.*, (2015) and Sivia *et al.,* (2017). Among all these eighteen crosses H 1465 x H 1464 (35%), H 1353 x H 1480 (33%), H 1098i x H 1464 (32.33%), H 1098i x H 1470 (28%) and H 1353 x H 1499 (26.33%) registered high heterosis over twenty five per cent for boll weight (g). Similar records were reported by Jaiwar *et al.,* (2012), Tuteja *et al.,* (2014), Reddy *et al.,* (2016) and Lingaraja *et al.,* (2017b).

For Ginning outturn the range of heterosis varied from -29.73 pre cent (H 1465 x H 1491) to 24.36 pre cent (H 1353 x H 1464) for GOT. Only four crosses manifested highly significant positive heterosis over the check HHH 223. The crosses H 1353 x H 1464 (24.36%), H 1316 x H 1505 (18.92%) and H 1465 x H 1499 (10.62%) were highly heterotic in nature. The hybrids H 1353 x H 1464 (good x poor) and H 1316 x H 1505 (poor x poor) exhibited positively significant heterosis. For this trait heterosis was also observed by the workers Solanki *et al.,* (2014), Tuteja *et al.,* (2014), Sivia *et al.,* (2017) and Chakholoma *et al.*, (2021).

In case of seed index out of fourty four cross combination only twenty two crosses registered highly significant positive heterosis, and the hybrid H 1316 x H 1500 (37.93%) revealed the maximum superiority over check followed by H 1316 x H 1481 (27.59%), H 1465 x H 1490 (25.86%) and H 1465 x H 1480 (24.14%). the range of heterosis for this trait was -6.9 to 37.93 per cent. Heterosis for this trait was also studied by the earlier workers Dave *et al.,* (2014), Solanki *et al.,* (2014), Sawarkar *et al.*. (2015), Sivia *et al.,* (2017) and Chakholoma *et al.* (2021).

Heterosis range varied from -65.68 to 31.63 per cent for lint index and solely five crosses registered positive heterosis value. The cross H 1316 x H 1505 was the hybrid showing maximum (31.63%) positive heterotic effect accompanied by H 1465 x H 1499 (27.67%) and H 1098i x H 1501 (22.09%). Similar result was observed by Dave *et al.*, (2014), Solanki *et al.,* (2014), Pushpam *et al.,* (2015) and Sivia *et al.,* (2017).

Seed cotton yield/plant is the prime trait in cotton. The hybrid H 1353 x H 1499 (119.28%) was registered as a superior hybrid among all the hybrids. Heterosis range varied from -20.65 to 119.28 per cent for the prime trait. The other crosses revealed superiority over check were H 1353 x H 1480 (112.67%), H 1353 x H 1491 (105.23%) and some other important crosses also showing >80 per cent haterosis for this main trait were H 1098i x H 1481 (93.86%), H 1353 x H 1501 (87.54%) and H 1316 x H 1491 (82.57%). Among all F_1 hybrids six hybrids H 1353 x H 1499 (good x good), H 1353 x H 1480 (good x good), H 1353 x H 1491 (good x poor), H 1098i x H 1481 (poor x good), H 1353 x H 1501 (good x poor) and H 1316 x H 1491 (poor x poor) registered heterosis of more than 80. Heterosis for seed cotton yield and other related characters in cotton has also been reported earlier by Reddy *et al.,* (2016), Lingaraja *et al.,* (2017), Vekariya *et al.,* (2017), Sivia *et al.,* (2017), and Chakholama *et al.,* (2021).

CONCLUSION

All the tested characters depicted significant economic heterosis in desirable direction over check hybrid HHH 223. Out of forty four crosses the maximum heterosis for yield of seed cotton per /plant was registered by the cross H 1353 x H1499 (119.28%) followed by H1353 x H1480 (112.67%), H1353 x H1491 (105.23%) and some other important crosses exhibited leading positive significant heterosis for yield of seed cotton were H 1098i x H 1481 (93.86%), H 1353 x H 1501 (87.54%) and H 1316 x H 1491 (82.57%). Crosses exhibiting heterosis for seed cotton yield/plant also reported heterosis for bolls/plant and boll weight. The test hybrids showed heterosis of more than 80 pre cent and hence permit their further testing over several locations for commercial utilization.

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Received for publication : June 19, 2022
Accepted for publication : June 30, 2022